How Long Can You Irrigate Without Runoff?

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When you irrigate, the one thing you want to avoid most is to overirrigate. That is, you don't want to irrigate so much that you waste water--and dollars--when rivers start forming at the edges of a site. To keep from doing so, you need to determine what that maximum runtime is. Infiltration equations are the key.

Using infiltration equations, you can avoid or minimize irrigation runoff. Here, I'll discuss equations I developed that will help you determine what the maximum sprinkler-irrigation runtime should be on your site. We'll also use Kostiakov's and Horton's infiltration equations to help guide you in finding a practical solution to runoff problems.

What are these equations? I used infiltration-test data on bare soil for five types of soil textures (see table, page 42) to produce a series of curves representing the relationship between the maximum sprinkler-irrigation runtime and the sprinkler precipitation rate with different land slopes. You can use these curves to determine the maximum sprinkler runtime for your calculated sprinkler precipitation rate according to your soil type and your land-slope conditions. (Keep in mind, however, when referring to these curves that, because the raw data used to construct the curves was based on bare soil, you should reduce the result from the curves if you're irrigating turfgrass.)

The Hung equation is: $t_{max} = (1/Pb)\{f_o - P + f_c[\ln (f_o - f_c)/(P - f_c)]\}$ where: t_{max} = Maximum irrigation runtime without runoff (hours) P = Average sprinkler precipitation rate (inches/hour) b = Horton's constant (see table, page 42) f_o = Infiltration rate (inches/hour) at the start (at time) f_c = Basic infiltration rate or saturated infiltration rate = Constant (inches/hour).

We based the infiltration data (obtained from the U.S. Natural Resources Conservation Service--USNRCS) on a 50-percent-available soil-water depletion rate--data that U.S. researchers have used for almost a century in irrigation applications. You can change the percent of available soil-moisture depletion anywhere from 25 to 75 percent. However, as mentioned, the USNRCS based its infiltration test data on the depletion of 50 percent available soil moisture. I constructed all curves based on the above assumption. Therefore, it's best to use the prepared curves if the available soil-moisture depletion is 50 percent or less.

I then applied Kostiakov's equation to obtain infiltration rate vs. test elapsed time. Kostiakov's equation is: $I = K ta$ where: I = Accumulative infiltration rate (inches) K, a =

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Constants that depend on the soil and initial conditions t = Time after infiltration starts (hours)

In differentiating the first equation with respect to time "t," we have: dI/dt = K a t a - 1

where: dI/dt = Infiltration rate (inches/hour)

Based on this third equation, I obtained infiltration rates at various times from the USNRCS raw infiltration data for the five soil types. I plotted the infiltration rates vs. the elapsed time to obtain the best infiltration capacity curves through the Macintosh Cricket computer-software program for the five soil types.

Figures 2 through 6 (at right) depict the reduced maximum irrigation runtimes for the five soil types on land slopes from 0 to 5 percent, 6 to 8 perce nt, 9 to 12 percent and 13 to 20 percent.

As mentioned in the footnote of the table (page 42), the USNRCS obtained the five "b" values for the five types by solving Horton's equation using the infiltration-capacity curves shown in Figure 1 (above right).

Horton's equation is: f = fc + (fo - fc) e -bt

where: f = Infiltration rate (inches/hour) fo = Infiltration rate at time = 0 fc = Basic infiltration rate (inches/hour) b = Horton's constant t = Elapsed time (hours)

Now that you're familiar with the formulas, let's look at some examples in which you can apply the information you've learned. I developed this information into Figures 2 through 6 (above), as mentioned.

Putting the formulas into real-world equations

Example 1: Imagine your sprinklers cover an area of 20 x 20 feet. They have a total flow rate of 8 gallons per minute (gpm). What, then, is the maximum runtime per application? Let's assume your soil is loamy and the land slope is 6 percent. You first must calculate the average precipitation rate (PR): Precipitation rate (inches/hour) = (96.3 x gpm)/A

where: 96.3 = Conversion factor A = Area (square feet)

Thus, the PR = (96.3 x 8)/(20 x 20) = 1.92 inches/hour. Now look to Figure 3 (previous page) with this information. There, you see that for the PR of 1.92 inches per hour, on loam soil with a slope of 6 to 8 percent, you have a maximum runtime of about 30 minutes.

Example 2: You have a flat turf area, 40 by 40 feet, irrigated by sprinklers with a total flow rate of 30 gpm. The soil is sandy loam. Knowing this, find the maximum runtime for the sprinklers per application.

Using the same formula, your PR = (96.3 x 30)/(40 x 40) = 1.81 inches/hour. >From Figure 2, you find that for the PR of 1.81 inches per hour, on sandy loam soil and a slope of 0 to 5 percent, you have a maximum runtime of 70 minutes.

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If, after you've figured your required irrigation runtime and it exceeds the maximum runtime, then you'll need to make repeated cycles of application. In this case, the required irrigation runtime depends on following several primary factors: Irrigation frequency Evapotranspiration (ET) rate Precipitation rate Maximum soil-moisture holding capacity Percent of the available soil-moisture depletion Overall irrigation efficiency.

Within the maximum soil-moisture-holding capacity, if the required irrigation runtime exceeds the allowable maximum runtime, then you must cut short the irrigation-application time, and you need repeated cycles.

Example 3: Assume that your soil is the same as in Example 1 (loamy soil). Use the sprinkler PR from Example 1 (1.92 inches/hour) with the following additional data: Land slope = 0 to 5 percent ET rate = 0.24 inches per day Field capacity (FC) = 22 percent (by weight) Permanent wilting point (PWP) = 10 percent (by weight) Apparent specific gravity (As) = 1.40 Available soil-moisture depletion (C) = 50 percent Grass root depth (D) = 6 inches = 0.5 feet Overall irrigation efficiency (E) = 75 percent.

You can use the formula to calculate the required irrigation water and runtime. The required irrigation water in inches per irrigation application is:

R = C (FC-PWP) as D/100 = 0.5 (22-10) 1.4 x 0.5/100 = 0.042 inch

Thus, the required irrigation runtime per application is:

t - R/(PR x E) = 0.042/1.92/0.75 = 0.060 hour = 54 minutes

You can calculate irrigation frequency as:

Lf = R/ET = 0.042/0.24 = 0.18 day

Perhaps you want to adjust the irrigation frequency from 2.1 days to a whole number of days, such as 2. Then, you would change the amount of water you should apply per irrigation application to:

Radj = (2/2.1) x R = 0.952 x 0.042 = 0.04 inch per irrigation

In Example 1, the maximum irrigation runtime allowed for the selected sprinkler is 30 minutes and the actual irrigation runtime is 54 minutes. So the selected sprinkler probably is not adequate.

Of course, you may think you could simply change nozzles if you've figured your required irrigation runtime and it exceeds the maximum. However, keep in mind that, on an existing system, if you change the nozzle size, it will affect the flow rate and the distal water pressure at the nozzle. You'll also change the diameter of a sprinkler's throw and distort the distribution uniformity.

The distance of throw depends on two main factors: the nozzle's water pressure (or flow velocity--not flow rate) and the angle (with the horizontal plane) of the water-stream trajectory. For example, if you reduce the nozzle size, the outlet will reduce the flow rate. Thus, you should reduce the water pressure loss along the water's travel path. You'll recover the distal water pressure to a higher level. Consequently, the velocity at the nozzle outlet increases and the distance of throw increases. This means your sprinkler will cover more area--but it'll take you longer to water.

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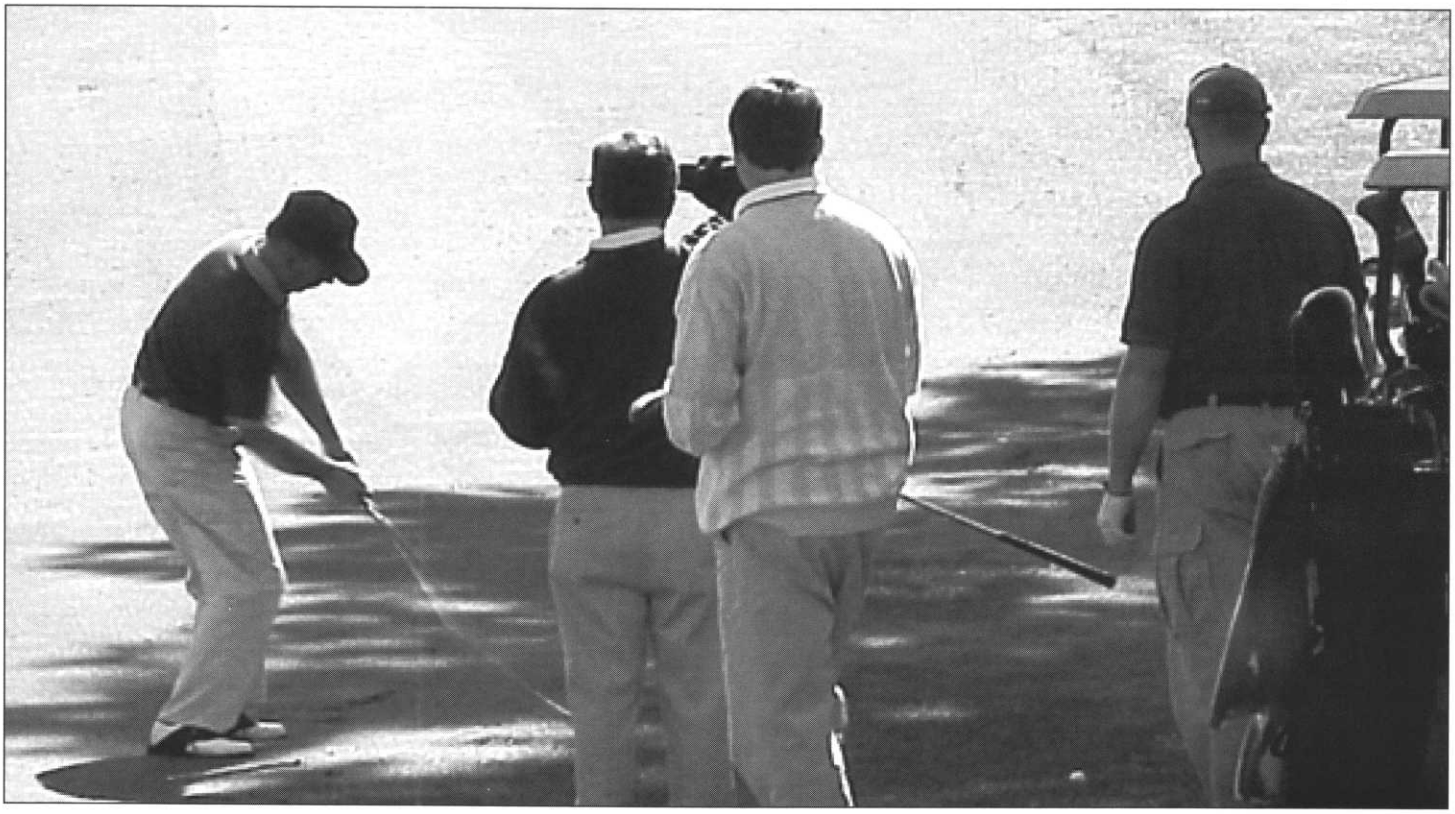

JOHN QUEENSLAND, superintendent at Cedar River CC hits his second shot on the 10th hole during the 2001 Stodola Research Scramble at Edina Country Club on September 25th. Others in John's group include Brian Bergone, Mike Schneider and Jack Kleahn.